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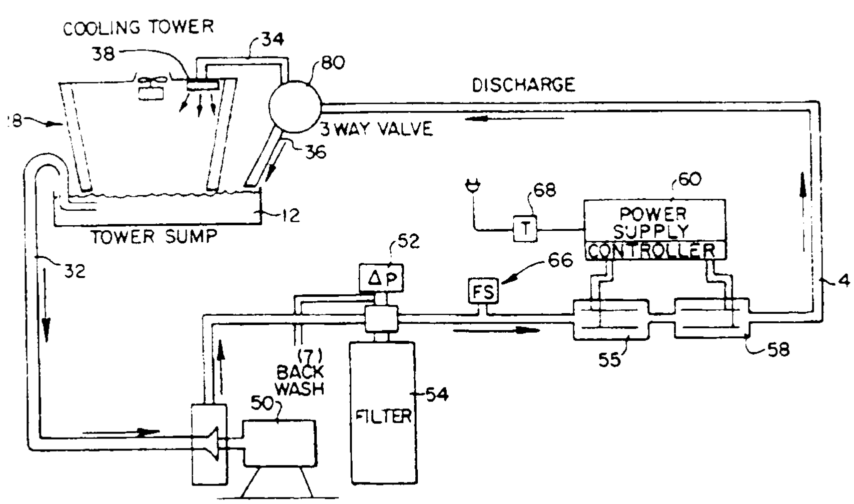

(57) Abstract

... for water treatment, and in particular for the electronic oxidation and ionization of water in combination with a filter apparatus for providing a totally no-chemical method for controlling biofilm, corrosion and scale in the condensing water loop of a cooling water system in commercial, industrial and power generating applications. Water to be treated is filtered in an automatic backwashing filter tank (54) which contains layers of various filtration media. After filtration the water is passed through ionization chambers (55, 58) wherein metal, hydrogen, and oxygen ions are introduced into the water by the use of plasma fused iridium coated titanium electrodes and copper electrodes. After ionizing the water, the water is dispersed uniformly and completely over the water side surfaces of the cooling tower (18) and circulated through the condensing loop to control biofilm, scale and corrosion.

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SYSTEM AND METHOD FOR THE ELECTRONIC TREATMENT OF COOLING TOWER WATER

Technical Field of the Invention

The present invention relates generally to the treatment of cooling tower water to control scale, corrosion and biofilm, and more particularly to an electronic oxidation and ionization apparatus and methods with side-stream filtration.

Background of the Invention

Condensing water loops are well known and used as coolant or mass heat transfer systems for such things as power plants. Generally, water loops comprise a cooling tower, a condenser system and a pump. In refrigeration cycles using condensing water loops, the function of the cooling tower is to cool condenser water after it has removed heat from the refrigerant in the condenser. In industrial processes, the condenser has the burden of condensing chemical products over a given temperature range from vapor to condensate. In power plants, the condensing water is used to draw heat from the spent steam driving the turbines. The cooling tower in each of these applications is a mass heat transfer device. In refrigeration and air conditioning systems, the colder the water is entering the condenser, the less energy required to power compressors on the refrigerant side of the condenser. In chemical product manufacturing, the colder the water, the more efficient the condensation process and therefore the greater the volume of product produced at a lower cost. In electrical power generation, the warmer the water, the less efficient the power generation, thereby depriving the facility of additional power sales. In all applications, the less fouling on the cooling tower surfaces and in the waterside condensing tubes, the more efficient, economical and long lasting the system will be.

Water in a condensing loop draws heat from the refrigerant/chemical product/steam as it passes through the condenser. In the cooling tower, the heated water is cooled by evaporation and the mixing of cooler make-up water. Cooling towers come in various types and sizes. For example, there are atmospheric towers, hyperbolic natural draft towers, counter flow and cross flow natural draft towers, mechanical draft towers using either forced draft or induced draft, and hybrid draft

towers which are fan assisted natural draft towers. The common element in each is a reduction in temperature of the condensing water coming off the condenser and returning the water to the condenser as close to the design temperature as possible. In all types of cooling towers (except dry towers) evaporation is the means of cooling the water. The towers are designed to expose the maximum transient water surface to the maximum air flow for the longest possible period of time. As a result, a portion of the water in the loop is lost in this process when it is discharged into the atmosphere as hot moist vapor (the "plume"). The cooling tower is a device that takes heat out of the circulating water and discharges the heat into the atmosphere. Water volume lost in this process is replaced by new water introduced into the basin of the cooling tower by means of make-up water piping to maintain a constant volume of water in the system.

Description of the Water Chemistry of Condensing Water Loops:

A description of the water chemistry of the condensing water loop has three components. The first component is the water chemistry of the make-up water. The source of the water will determine some of the dissolved solids and gases, colloidal solids, and suspended solids in the condensing water loop. Typical among these are dissolved forms of carbon dioxide (carbonic acid, bicarbonate ion and carbonate ion), calcium, sulfates, silica, chlorine or bromine compounds from purification efforts, nitrogen compounds, dissolved oxygen and hydrogen sulfide, and the hydrated oxides of iron and manganese (See Table 1). If the make-up is treated waste water or reused process water, it may also contain phosphates. Another source of the make-up water may be treated or untreated ground water or lake water.

Table 1: Common Ions Found in Make-up Water

calcium	Ca^{++}	bicarbonates	HCO_3^-
magnesium	Mg^{++}	chloride	Cl^-
sodium	Na^+	sulfate	SO_4^-
iron	Fe^{++}	nitrate	NO_4^-
manganese	Mn^{++}	carbonate	CO_4^{--}
copper	Cu^{++}	phosphate	PO_4^{--}

The second component in the water chemistry is the air borne particles and gases in the ambient air. The design and function of cooling towers insures that the water circulating through them will scrub gases and particles from the air passing through the tower. In addition to the normal atmospheric gases, the ambient air may also contain sulphur dioxide and ammonia. Solids of silts (silica), salts, clays (alumina), ash, and organic solids such as pollen, leaves, molds, bacteria, and spores of other living organisms are also contained in the ambient air.

The third source of components for water chemistry of the water in the condensing loop is the piping, valves, pumps, and equipment (including the condenser, tower, and basin) with which the water comes in contact while circulating. Also included in this component, are the chemical or organic compounds added to the water to control scale and corrosion. Condensing water loop piping is usually a system incorporating several different metals, including mild steel, brass, copper, stainless and galvanized steel. The cooling tower often will have pressure treated woods, concrete, plastic, and asbestos that will contact the water as it circulates. Salts, liquids or gases of chlorine or bromine, chromate compounds, and magnesium compounds may be added to the water to control bacteria, algae, corrosion or scale. Since the water is the closest to a universal solvent, it will tend to dissolve a little of almost everything it comes in contact with. This leads to corrosion of system piping, valves and equipment creating compounds of zinc, copper, nickel and iron rust, leaching of arsenic and other compounds out of the cooling tower surfaces, and dissolving calcium compounds from concrete basins. As the water evaporates, the solids remain, increasing their concentration in the circulating water. The increased concentration accelerates corrosion, and coats the system's piping, valves and equipment. The heavier dissolved particles will settle out, primarily in the cooling tower basin and sump, but also in low pressure or restricted areas in the loop.

The accumulation of concentrated solids from the combined effects of evaporation, air scrubbing, leaching and corrosion together with the additive additions leads to a condition called "fouling." The damp, warm, and dark conditions in the cooling tower and the basin leads to the rapid growth of algae, bacteria, fungus, and other organic compounds generally and commonly referred to as "biofilm." The

circulating water is rich in dissolved oxygen and other nutrients to further enhance the growth and spread of the biofilm. The biofilm tends to trap and hold the solids in the circulating water. This mass, when it settles to the bottom of the basin and the sump, becomes an insoluble and restricting sludge. Also, since some of the solids are the product of air borne pollution and the result of chemicals used for attempting to control biofilm, fouling, scale and corrosion, the sludge can contain potentially toxic levels of chemical compounds.

Description of Scale and Corrosion in the Condensing Loop System:

Scale, while being only one of the deposits that may form and be found on surfaces of the condensing water loop system, is generally the name given to all deposits found in the system. In fact, scale is defined as a deposit of a crystallization of a dissolved salt when its concentration exceeds its solubility. A true scale will re-dissolve without chemical change if the water composition is so altered that the water becomes unsaturated with respect to the precipitated compound. Condensing water loops will have scales of calcium carbonate, and calcium sulfate where sulfuric acid has been used for scale control. Calcium phosphate is often found in systems using sewage treatment effluent for makeup. Magnesium hydroxide is found in systems where magnesium is used as a corrosion inhibitor, and magnesium sulphate where sulphuric acid has been used for scale control. Barium sulphate is also found in systems where barium is used as a corrosion inhibitor and sulphuric acid is used for scale control. Sodium chloride deposits are often found in systems where chlorine has been used as an oxidizer for biofilm control. Where silica and silicates are in the water, they will combine with the other scale forming salts to create a very hard and particularly insoluble scale. The most common form of silica scale is calcium silicate which is a superior insulating material that can drastically reduce condenser thermal efficiency as well as restrict the flow through the heat exchanger.

Corrosion is an electrochemical process that takes place to some extent whenever a metal, water, and depolarizing agent are brought together. Any condition that causes one point on a metal surface to differ from another will permit corrosion to occur. The galvanic action of two different metals joined together in the presence of water will initiate corrosion on the more anodic of the two. Because corrosion is

chemical, its rate increases with heat, therefore being the greatest in the condenser and on the condenser discharge side of the loop. Corrosion, like scale, is controllable and, to a limited extent, reversible with the proper maintenance of water chemistry balance.

Corrosion and scale are associated problems but the effect and cause should not be confused. The essential effect of corrosion is to destroy metal; scale, on the other hand, tends to clog open sections and to line surfaces with deposits. The products of corrosion often contribute to scale formation and aggravate the problem of its treatment.

Description of Fouling on Cooling System Operation:

Any film or deposit which forms on the waterside heat exchange surfaces reduces the heat exchange efficiency of the system (See Table 2). System efficiency is further reduced by maintenance shut downs for removal of deposits, and the repair or replacement of piping, valves, and equipment abraded by the suspended particles in the water or damaged by corrosion.

Table 2: Heat Loss from Condenser Tube Scale (%)

Scale Thickness Inches	Soft Carbonate	Hard Carbonate	Hard Sulphate
1/50"	3.5	5.2	3.0
1/32"	7.0	8.3	6.0
1/25"	8.0	9.9	9.0
1/20"	10.0	11.2	11.0
1/16"	12.5	12.6	12.6
1/12"	15.0	14.3	14.3
1/9"	---	16.0	16.0
1/8"	---	25.0	25.0
1/4"	---	50.0	50.0

Blowdown of the tower basin and sump has been the primary method of controlling the buildup of the suspended solids concentration in the circulating water. This process is expensive, wasteful of water, and potentially hazardous. The

blowdown process requires that thousands of gallons of basin and sump water be dumped periodically and replaced with new make-up. Towers using municipal water supplies must purchase the make-up. The dumped water will also remove additives placed in the system to control biofilm, scale, and corrosion. Since some of these additives are potentially hazardous, the blowdown water must be discharged into approved sewers, with the accompanying costs, and must be monitored and reported, at an additional maintenance cost.

Another method employed to reduce or control the buildup of suspended solids in the condensing loop water is side-stream filtration. In this method, a portion of the circulating water (usually 1% to 10%) is drawn off and run through filters to remove the suspended solids. This method, while effecting the buildup of suspended solids, still requires the introduction of compounds to control biofilm, scale, and corrosion. Therefore, the filter discharge and the sludge will still contain potentially hazardous compounds requiring special discharge methods and controls.

Ozonization is also used in some systems and applications to replace chemical or organic biocides. Ozone, while an effective biocide, cannot by itself address all forms of organic matter which may foul the cooling water system. Ozonization will not eliminate the need for chemicals to control scale or corrosion. Unless used with side-stream filtration, blowdown will still be required to control the buildup of suspended solids. Potentially toxic compounds in the blowdown discharge (or filter discharge) and in the sump sludge will still exist with an ozonization system.

Magnetics, electrostatic charges and ultrasonic waves have also been used in some systems in a non-chemical attempt to control scale and corrosion. All of these methods still require the use of chemical or organic compounds for biofilm control, with the resulting potentially toxic blowdown and sump sludge discharge problems noted above. Also, unless coupled with side-stream filtration, none of these methods fully address the buildup of suspended solids.

As already noted, the introduction of chemical or organic oxidizers have been used as a method of controlling biofilm, but the oxidizers accelerate

corrosion. Chemical oxidizers form potentially toxic compounds, while organic oxidizers do not form potentially toxic by-products.

To control scale and corrosion, some systems use chemical inhibitors. These chemicals are introduced into the circulating water to form insoluble oxides to coat the metallic surfaces to inhibit corrosion and provide a surface that is less likely to attract and hold scale forming compounds. These chemicals do not inhibit scale formation on the non-metallic surfaces of the cooling tower. The by-products of the scale inhibiting chemicals are potentially toxic, requiring expense for the discharge and control of the by-products. The chemical reaction with the circulating water results in new compounds being formed which add to the suspended solids burden of the water. The insoluble oxides formed to inhibit scale and corrosion, when deposited on the walls on the waterside condensing tubes, form an insulating layer, reducing the thermal efficiency of the condenser.

Another method of attempting to control scale and corrosion is the use of self-sacrificing magnesium anodes to coat the metallic surfaces with magnesium hydroxide to inhibit corrosion. Similar to the effects of the inhibiting chemicals noted above, magnesium hydroxide only inhibits corrosion of the metallic surfaces and it has no effect on the corrosive and leaching properties of the circulating water on the non-metallic surfaces of the tower and basin. Also similar to the chemical inhibitors, the magnesium hydroxide coating on the waterside of the condenser tubes is a thermal insulator decreasing the thermal efficiency of the condenser.

All existing methods of controlling fouling require (i) blow down, (ii) sanitary sewer or environmentally acceptable methods of discharging blowdown water or backwash water from side-stream filtration, (iii) expensive and time consuming additions of additives to control biofilm, scale, and corrosion, (iv) special procedures for the removal and disposal of sump sludge when potentially toxic compounds are precipitated as by-products of the chemical treatment to control biofilm, scale, or corrosion, and (v) the loss of thermal efficiency at both the waterside of the condenser and within the tower due to scale buildup. Even with inhibitors, periodic brushing of the condenser tubes and the tower surfaces is necessary to remove scale. When the method employed for the control of buildup of suspended solids is periodic blow-down, then the recurring buildup will abrade the surfaces of the condensing loop

piping, valves, pumps, and condensers decreasing their design life and increasing maintenance costs.

Further prior art includes U.S. Application, Serial No. 08/340,743 to Snee entitled "Electrical Water Purification Devises and Methods", which is herein incorporated by reference, discloses a water purification system including (in one exemplary embodiment) a pair of electrodes, at least one of which comprises a plasma fused iridium coated titanium electrode used for the purpose of creating oxygen, hydrogen, and hydroxyl ions in the treatment of water; and according to another aspect of the invention, embodies a pair of copper electrodes to provide copper ions for the control of algae and bacteria. This Snee invention further provides a filtration and method of using these electrodes.

U.S. Patent No. 5,007,994 to Snee, entitled "Water Purification System", which is herein incorporated by reference, discloses a water purification system using a pair of carbon electrodes and a pair of copper electrodes submersed in the water to be filtered. When a potential is applied across these electrode pairs, the copper electrodes release copper ions, while the carbon cathode produces hydrogen ions and the carbon cathode produces oxygen ions. These ions produce a beneficial water treatment effect. Carbon electrodes are, however, subject to wear and have a limited life. The present invention provides an improved water treatment system and method.

The present invention provides a more efficient, economical and improved apparatus and method for the control of scale, corrosion and biofilm in the condensing water loop of a cooling water system using electronic oxidation and ionization with side-stream filtration.

Summary of the Invention

According to the preferred embodiment of the invention, there is provided a condensing water loop side-stream (or by-pass) filtration and treatment system in a self contained skid-mounted apparatus. Condensing water is drawn off the discharge side of the pump and prior to the condenser, routed through the side-stream (or by-pass) filtration and treatment apparatus and returned to the condensing loop down stream of the condenser and prior to the cooling tower. According to an

alternative embodiment of the invention, condensing water is drawn from the cooling tower basin and routed through the apparatus and returned to the cooling tower spray deck. The water is drawn out of the condensing loop (or in the alternative, out of the basin) and through the apparatus by use of a pump mounted on the apparatus. The drawn water is pumped through an automatic backwashing, multimedia filter, which is also mounted on the apparatus. The use of the filter may not be required if blowdown (or purge) is not an economic concern to the cooling tower operator. Following the filter (if used), the drawn water is pumped through two separate electrode chambers, the first of which includes a pair of electrodes at least one of which comprises a plasma fused iridium coated titanium electrode used for the purpose of creating nascent oxygen, molecular oxygen, ozone, hydroxyl and perhydroxyl radicals, and hydrogen peroxide in the treatment of the water. These electrodes also create a flux field which aligns the polarity of the dissolved and suspended metallic salt compounds as part of the method of controlling scale. According to one alternative embodiment of the invention, a commercially available self-contained unit for the production of ozone may be substituted in lieu of, and instead of, the electrode chamber containing plasma fused iridium coated titanium electrodes. The second electrode chamber contains a pair of electrodes formed of copper which provides copper ions for the control of biofilm (algae, bacteria and fungus) in the condensing water loop and on the cooling tower surfaces. This second set of electrodes also creates a flux field similar to the first set of electrodes. After the second electrode chamber, the filtered and treated water is returned to the condensing loop for discharge over the cooling tower surfaces and circulation through the condensing water loop. According to one alternative embodiment of the invention, the condensing water may be returned to the condensing loop without going through the second electrode chamber containing a pair of copper electrodes. In this alternative, make-up water would be routed through the second electrode chamber containing a pair of copper electrodes and returned to the cooling tower basin.

It is a purpose of the present apparatus and method to prevent scaling, biofilm and corrosion within a condensing loop without the use of chemicals.

Brief Description of the Drawings

Figure 1 shows a general schematic illustration of a conventional condensing water loop used as coolant or mass heat transfer system.

Figure 2 shows a schematic illustration of an alternative embodiment of the condensing loop of the present invention.

Figure 3 shows a schematic illustration of an alternative embodiment of the condensing loop of the present invention.

Figure 4 shows a schematic illustration of the makeup loop embodiment of the condensing loop of the present invention.

Figures 5(a-c) show a schematic illustration of the water treatment apparatus of the alternative embodiments of the condensing loop shown in figures 2-3.

Figures 6(a-c) show a schematic illustration of the water treatment apparatus of the alternative embodiment of the condensing loop shown in figure 4.

Figures 7(a-c) show a further detailed schematic illustration of the water treatment apparatus of the alternative embodiments of the condensing loop shown in figures 2-3.

Figure 8 shows a schematic illustration of an alternative embodiment of the water treatment apparatus of the embodiments show in figures 2-3.

Figure 9 shows a schematic illustration of an alternative embodiment of the water treatment apparatus of the embodiment show in figure 4.

Figure 10 shows a further diagram of the embodiment shown in Figure 3.

Figure 11 shows a schematic illustration of the electronic system which controls the water treatment apparatus.

Figures 12(a-b) show side view and end view cross-sections, respectively, of the basin water pick up pipe of the present inventive apparatus.

Figure 13 shows an illustration of the oxidation chamber showing flux field and effect on metallic compounds.

Detailed Description of the Invention

With reference to the drawings, Figure 1 illustrates a general schematic illustration of a conventional condensing water loop (HVAC) mechanical system with the condenser water loop used as coolant or mass heat transfer system. In Figures 2-4

there is provided schematic illustrations of the condensing water loop of the present invention showing the positioning of the side-stream (or by-pass) filtration and treatment system in a self contained skid-mounted apparatus. The water treatment apparatus (WTA) of the present invention is generally indicated by reference numeral 10.

Figures 2-4 provide illustrations of the pathways of the various embodiments of the invention. In the embodiment of Figure 2, as the cooled water is pumped from the basin 12 of the cooling tower 18 through piping 14, it travels through pump 16. After the water is forced through the pump 16 and into piping 20, a portion of the water is diverted through smaller piping 22. The water diverted through piping 20 passes through the condenser 24, absorbing the generated heat, and up through piping 26. The water which was diverted after the pump 16 travels up through the WTA 10 at inlet 1. Waste water exits the WTA 10 at waste exit 7 and the treated water exits the WTA 10 at exit outlet 4. The treated water reenters the water loop at point 28 into piping 26. The combined water is sprayed onto the cooling tower 18 through spray nozzles 30, thus cooling the water, dissolving the scale on the cooling tower surfaces 36, and oxidizing biofilm on the surfaces 36 and in the basin 12.

Figure 3 illustrates a further pathway embodiment. In this case, a portion of the water is drawn from the basin 12 through piping 32 and into the WTA 10 at inlet 1. As the treated water exits the WTA 10 via 4, it is reintroduced into the water loop by piping it into the cooling tower through piping 36, or it is reintroduced into the top of the cooling tower through piping 34 via 3-way valves. In the latter case, the treated water is sprayed down the sides of the cooling tower via dispersion sprayers, or tower top misters 38.

Figure 4 illustrates a further pathway embodiment. In this case, similar to Figure 3, a portion of the water is drawn from the basin 12 through piping 32 and into the WTA 10 at inlet 1. As the treated water exits the WTA 10, it is reintroduced into the water loop by piping it into the cooling tower through piping 36, or it is reintroduced into the top of the cooling tower through piping 34 as in Figure 3. In this embodiment, a portion of the make-up water which is introduced into the cooling tower 18 through piping 6 is diverted through smaller piping 40 into the WTA 10 at

the makeup water intake 2. After the makeup water is treated through the Cu side loop application, which is further explained below, it exits at the makeup water discharge 3 and is introduced into the cooling tower 18 through piping 42.

Figures 5a-c show a more detail illustration of the WTA in Figures 2-3. Figure 5a shows a side view of the WTA. As the water is diverted from the loop it enters the WTA at the intake 1 and flows through pump 50, which pumps the water up into a pressure differential valve (PDV) 52, or control box, which diverts the untreated water down through an optional multimedia sediment filter tank 54. The filter is preferably a Multimedia depth filter. Any fiberglass automatic filter may be used, depending on the flow rate. Such filters are well known and can be procured from Alamo Water Refiners, Inc. (N5240-13). As the filtered water exits the filter 54 the PDV 52 diverts the waste water out through exit 7 and the treated water is diverted through an electrode treatment zone 55, which houses two separate electrode chambers 55, the first of which includes a pair of electrodes 56 at least one of which comprises a plasma fused iridium coated titanium electrode. The second electrode chamber contains a pair of electrodes 58 formed of copper. After the second electrode chamber 58, the filtered and treated water is returned to the condensing loop via outlet 4 for discharge over the cooling tower surfaces and circulation through the condensing water loop. Figures 5b and 5c show top and end views, respectively.

Figures 6a-c show a more detailed illustration of the WTA in Figure 4. Figure 6a shows a side view of the WTA. According to this alternative embodiment of the invention, the condensing water is returned to the condensing loop without going through the second electrode chamber 58 containing a pair of copper electrodes. In this alternative, make-up water 2 would be routed through the second electrode chamber 58 containing the pair of copper electrodes and returned to the cooling tower basin via 3. Figures 6b and 6c show top and end views, respectively.

Figures 7a-c show a preferred configuration of the components of the WTA in Figures 2-3. Figures 7a & 7b show the preferred configuration of the skid, including the plumbing, filter, electronics and pump. Figure 7c shows an internal side view of the electrode chamber, the electronics and the pathway of the water to be treated. As the water is diverted from the loop it enters the WTA at the pump 50 intake 1 and flows through pump 50, via a flowswitch 62, which pumps the water up

into a pressure differential valve (PDV) 52, or control box, which diverts the untreated water down through an optional multimedia sediment filter tank 54. As the filtered water exits the filter 54 the PDV 52 diverts the waste water out through exit 7 and the treated water is diverted through ball valve 64 and flowswitch 66 through two separate electrode chambers 55, the first of which includes a pair of electrodes 56 at least one of which comprises a plasma fused iridium coated titanium electrode. The second electrode chamber contains a pair of electrodes 58 formed of copper. The electrode chambers are controlled by electronics 60 and a timer 68, further discussed below, which also controls the filter 54 and the pump 50. After the second electrode chamber, the filtered and treated water is returned to the condensing loop via outlet 4 for discharge over the cooling tower surfaces and circulation through the condensing water loop. The piping is preferably one inch PVC piping.

Figure 8 illustrates an alternative embodiment of the configuration of the electrode chambers for the embodiment shown in Figures 2 and 3. Similar to Figure 7c, the filtered water flows through ball valve 64, but is diverted either to chamber 58 or 56 via a 3-way solenoid valve. The diverted water flows through a flowswitch (70 or 72) and through the chosen electrode chamber and out through outlet 4. As above, the routing of the water is controlled by electronics 60 and timer 68.

Figure 9 illustrates an alternative embodiment of the configuration of the electrode chambers for the embodiment shown in Figure 4. Similar to Figure 7c, the filtered water flows through ball valve 64, but is diverted through flowswitch 74 only into chamber 56 and out into the basin of the cooling tower via outlet 3. The make-up water which is diverted through inlet 2 flows through flowswitch 76, chamber 58 and check valve 78 and out outlet 3. As above, the routing of the water is controlled by electronics 60 and timer 68.

Figure 10 further illustrates the treatment system of the embodiment shown in Figure 4, minus the cooling loop. The Figure shows a cooling tower ionization treatment piping diagram. As described above, the water to be treated is pumped (50) from the basin 12 via piping 32 into the pressure differential valve (PDV) 52, or control box, which diverts the untreated water down through an optional multimedia sediment filter tank 54. As the filtered water exits the filter 54 the PDV

52 diverts the waste water out through exit 7 and the treated water is diverted through flowswitch 66 and through electrode chambers 55 and 58. The chambers are controlled via the power supply controller (electronics) 60 which is actuated by the timer 68. After the second electrode chamber 58, the filtered and treated water is returned to the condensing loop via outlet 4 for discharge into the cooling tower 18. The treated water flows into a 3-way valve 80. The water is diverted either into the cooling tower through piping 36 into the basin 12, or it is reintroduced into the top of the cooling tower through piping 34. In the latter case, the treated water is sprayed down the sides of the cooling tower via dispersion sprayers, or tower top misters, 38.

Figure 11 shows a general schematic of the electronic flow pattern which is controlled by the power supply controller (electronics) 60 that sends direct current to the electrodes 56 and 58 on an alternating polarity and as described in the Snee patents.

Figure 12 shows a preferred 3 inch segment of the sump collection pipe. The pipe is preferably PVC piping and is 1½ inches in diameter with ½ inch holes. This portion of the piping is positioned in the basin of the cooling tower and functions to draw. water into the water treatment apparatus. The dots depict the surface of the inside diameter of the pipe and the penetrations of the holes through the pipe walls.

Description of the Electrochemical Aspects of the Invention:

The preferred embodiment of the present invention, as more particularly described in Figure 3, utilizes well known and accepted electrochemical reactions in combination with side-stream filtration and the oxidation process of U.S. Application, Serial No. 08/340,743 to Snee for a totally non-chemical method of controlling biofilm, scale, and corrosion, and the control of suspended solids buildup. The principles applicable to the process embodied in this invention have not previously been coupled together in the sequences and in combination with other methods to form a single apparatus as is exemplified by this invention.

The electrode chamber 58 containing two copper electrodes is, in accordance with the Snee application, connected to an electronic control unit 60 which provides a low voltage direct current charge to the electrodes with the polarity of such

electrodes alternating regularly on a preset cycle. In this invention, there is a timer 68 which may be set and adjusted so that the electrode chamber containing the copper electrodes 58 is only activated as needed in order to maintain a residual of copper electrons in the basin 12 water. As described in Snee, when the electrical charge is applied to the copper electrodes, one electrode is an anode and the other electrode is a cathode. The low voltage electromagnetic force imparted to the circulating waters disassociates some of the hydrogen and oxygen molecules forming the water to create dissolved hydrogen gas, oxygen gas, and free hydrogen ions. Additionally, at the face of the electrodes, positively charged copper ions are discharged into the stream. Preferably ionization of the Cu is maintained at 0.3-0.5 ppm. These are ionic copper charges and not molecular copper particles. The flux field created by the electrical charge to the electrodes polarizes the potential scale forming salt compounds in the circulating water (Figure 13). Molecules under normal conditions move at random, bonding to one another and clinging to surfaces 100. Upon entering the path of the flux field, the force is concentrated within the chamber, creating the proper energy required to polarize the molecules 102. After being treated, the internal forces orient the positive and negative poles, producing a molecular chain and resulting in flocculation of the solids 104, which forces the minerals to pass through the plumbing system. Existing scale will slowly flake off as the molecular chains loosen the bond and pull the minerals into the flow. Additionally, the flux field causes neutral particles, such as silica and alumina, to take on a negative charge as they pass between the electrodes, thereby enabling such charged particles to repel each other inhibiting their ability to form chains of insoluble scale. The copper ions are primarily used as a biocide and algicide, but additionally are used to replace the calcium in scale already formed within the system. The copper ions will combine with chlorine in the system to form copper chloride, an insoluble oxide that will inhibit any further calcified scale from forming. The dissolved hydrogen and hydrogen ions will combine with sulfides in the water to form insoluble particles. When the electrode chamber containing the copper electrodes is activated by the timer, the other electrode chamber containing the plasma fused iridium coated titanium electrodes 56 is not receiving an electrical charge. The ionized water is returned to the condensing loop where it is dispersed over the tower 18 surfaces acting as an effective biocide and re-dissolving and re-mineralizing scale

deposits on the tower surfaces. As the ionized water is drawn from the system, the insoluble calcium chloride, sulfide compounds and other suspended solids are trapped in the multimedia filter 54 and periodically back washed. Ionized particles and dissolved gases will pass through the filter and into the condensing water loop where the copper ions will replace calcium in any scale deposits in the condenser or condensing loop piping, valves or equipment and over time, re-dissolving and re-mineralizing such deposits. The copper ions remain in solution and act as a residual sanitizer throughout the condensing loop water system. The polarized scale forming salts and the negatively charged silica and alumina particles will be entrapped by the filter and discharged with the filter backwash. When the timer cuts off the power to the copper electrodes the electrolysis of the copper electrodes will cease.

In the preferred embodiment of this invention, the electrode chamber 56 containing the two plasma fused iridium coated titanium electrodes will operate at all times when the copper electrode chamber is not in operation. Similar to the copper electrodes, the electronics controller 60 provides a low voltage direct current to the electrodes with a regularly recurring alternation of polarities. As described in the Snee patent, these iridium coated titanium electrodes are inert and only provide an electromotive force for the disassociation of ions in the water passing between the two charged electrodes. The forces disassociate the oxygen and hydrogen from the water creating nascent (or atomic) oxygen, molecular (or atmospheric) oxygen, heavy oxygen (or ozone), hydroxyl and perhydroxyl radicals and hydrogen peroxide. Each of these are powerful oxidizers (see Table 3) with varying lives and stabilities. The primary purpose of the oxidizers is to "burn up" or oxidize all organic matter within the cooling water. Because the oxidation-reduction potential of the ionized form of these oxidizers is much greater than chlorine or bromine or the molecular forms of organic oxidizers (see Table 3), the result is a more efficient and effective oxidation of biofilm.

Table 3: Oxidation-reduction Potential of Water Treatment Oxidizers

CHEMICAL	SYMBOL	ORP RELATIVE VALUE
Fluorine	F	3.03
Hydroxyl Radical	[OH]	2.76

Atomic Oxygen	O	2.40
Ozone	O_3	2.07
Hydrogen Peroxide	H_2O_2	1.75
Permanganate	MnO_4	1.67
Hypobromous Acid	HOBr	1.59
Chlorine dioxide	ClO_2	1.50
Hypochlorous Acid	HOCl	1.49
Hypoiodous Acid	HOI	1.45
Chlorine (Gas)	Cl_2	1.36
Oxygen	O_2	1.27
Bromine	Br	1.09
Iodine	I_2	.54

The primary oxidizers used for water treatment are listed above. The oxidation-reduction potential ("ORP") indicates the power to oxidize. The foregoing is a list of oxidizers in the order of strength.

Additionally, the hydrogen peroxide dissolves rust and the oxide scale of the base metals that results from corrosion thereby returning the surface of the metal to a uniform molecular state. In addition to the oxidizers, the electromagnetic force between the iridium coated titanium electrodes causes the disassociation of some of the hydrogen and oxygen molecules forming the water, and creates positively charged ions which will combine with negatively charged chemical contaminants. The oxidizers will combine with dissolved minerals and iron which may be found within the condensing water. The molecular oxygen will combine with nitrites and convert them to nitrates. The oxidizers will transform sulphite and hydrogen sulphide to sulphate and colloidal sulphur. The oxidation of dissolved solids will allow the resulting insoluble oxides and hydroxides to settle out of solution so that they can be removed by the side stream-filtration.

The dissolved oxygen and ozone created at the electrodes combines with the transitional metals (copper, nickel, and zinc) found within the cooling water system to form an insoluble oxide of the metal itself inhibiting corrosion. Since the oxide is of the base metal itself, it does not have the insulating properties of the chemical oxides used as corrosion and scale inhibitors.

The titanium electrodes, similar to the copper electrodes, create a flux field which polarizes scale forming mineral salts and imparts a negative charge to the neutral particles of silica and alumina, thereby inhibiting their combination in the formation of scale deposits. The dissolved scale forming chemical compounds discussed above, and dissolved minerals which may be in the water that can cause scale, result in the water being "out of balance" electrically. One of the effects of the flux field is to create chains out of these oppositely charged compounds (See Figure 13) thereby tending to place the water in a state of electrical equilibrium or "balance." The cathodic plate, of the two iridium coated titanium electrodes, will increase the electron level of the water passing between the plates reducing the bonding of the oxygen atoms of the water molecules and the hydrogen atoms of the adjacent water molecules to create unbonded water molecules which are then more active in their combination with the dissolved chemical compounds and minerals in the water. Water in which the hydrogen bonding has been broken is said to be "conditioned" water. The balance of the water in the condensing water loop is not static because of the continual addition of dissolved chemical compounds and minerals from the addition of make-up to offset the effects of evaporation, combined with the addition of gases and solids scrubbed from the ambient air in the cooling tower. For this reason continuous oxidation of the water is necessary in order to maintain or move towards a balanced and conditioned water within the loop. Side-stream filtration of the precipitated solids resulting from the oxidation process assists in maintaining the water balance.

The ionized oxidizers of activated oxygen are effective biocides and algicides which remove and inhibit the growth of biofilm on the cooling tower surfaces and in the basin. Dead organic organisms are removed from the condensing water loop by the filter embodied in the apparatus. Since the biocides are not chemical, the backwash from the filter can be discharged without requiring the use of sanitary sewer or hazardous chemical monitoring. The ionized particles will pass through the filter and circulate through the system dissolving scale and creating insoluble oxides of transitional metals to inhibit further corrosion.

The most significant effect of this invention is to eliminate all chemicals currently used for the control of fouling and for corrosion inhibitors. Additionally, this invention will reverse and control scale and reverse and control corrosion by the

electrochemical action of the ionic particles created in the electrode chambers by mineral ionization of the copper and the activated oxygen ions.

The electromotive force that polarizes the minerals and conditions the water lowers the surface tension of the water making it a more effective and uniform conductor of heat. This property of the conditioned water will have two effects on the condensing loop water. First, on the waterside of the condenser, there will be a more uniform and consistent transfer of heat within the condenser to the water. Second, the reduced surface tension of the water will enable a more uniform and rapid dissipation of the transported heat to the atmosphere in the evaporation process within the cooling tower.

The elimination of scale and of insulating oxides formed by chemicals to inhibit scale and corrosion will increase the thermal efficiency of the system thereby reducing the operating pressures on both the water side and refrigerant/chemical product/steam side of the condenser. Lower operating pressures mean less operating costs (estimated to be up to a 25% savings) for the energy necessary to operate the system at the designed temperature ranges. In the chemical processing application, the increased thermal efficiency will enable a larger volume of saleable products to be produced within the same operating pressures as are currently being maintained with the traditional methods described in this application. In the power generation application, the increased thermal efficiency will enable a larger amount of saleable electricity to be generated within the same operating ranges and costs of the systems as they are currently being maintained.

The elimination of biofilm and scale from the tower surfaces will, with the introduction of ionized water, increase the evaporative effect of the tower. Since towers which have forced or induced drafts require the operation of fans in order to maintain the required temperature drop within the tower, the more effective evaporation resulting from this invention will reduce the need for the fans to maintain such temperature drop, thereby reducing the operating expense of the tower (estimated to be up to a 15% savings) and increasing the operating life of the fan motor and components.

The filter, as described in the Snee application and incorporated into the apparatus, along with its automatic backwashing capabilities, removes the

insoluble particles from the condensing water thereby removing those particles which would be susceptible to accumulation as a result of evaporation. The backwash of the filter would only occur as the sedimentation requires, and the volume of water necessary to back wash the filters is significantly less (estimated to be over a 90% savings) then the volume of water required by blowdowns to maintain the same concentration of dissolved solids within the system.

As previously noted above, the lower the volume of blowdown water, the less expense on the system for purchase of makeup water. Also, since no chemicals are involved in the invention, there are no sanitary sewer charges, no hazardous waste disposal costs, no potential pollution from the tower plume and no work place risks associated with the presence of hazardous chemicals.

The reduction of dissolved solids within the circulating waters, the elimination of corrosion accelerating chemicals, and the reduction of fouling deposits will all increase the operating life of the tower, pump, condenser, piping and fan motor (with an estimated life increase of up to five times the untreated life and up to two times the chemically treated life).

Finally, this invention requires less maintenance supervision than any other method, or combination of methods, currently utilized for the control of biofilm, scale and corrosion. It will reduce the periodic maintenance costs for cleaning the tower, basin and sump and should eliminate the need for periodic brushing of the condenser tubes, all at a substantial savings of manpower and labor.

Experimental Analysis:

An evaluation summary of the electronic non-chemical cooling tower water treatment system was conducted to test its effectiveness and efficiency. The system was installed on a cooling tower and condensing water loop. Several issues affect the condensing water loops that pertain directly to the proper operation and maximum efficiency of the HVAC system. The electronic system was evaluated in terms of how well it addressed each of the issues.

Electronic Treatment of the present invention:

The electrolytic system tested provides an environmentally friendly, chemical-free treatment for condensing water that controls scale, corrosion and biofilm This system, when combined with a filter, can control sump sludge. No chemicals means no hazardous materials. With the combined ingredients of "activated" oxygen and ionization, that are generated by the system, soft, sanitary water is provided to protect the equipment, the environment, and the budget.

The Test System:

The test HVAC system has two 286 ton centrifugal chillers connected to a nominal 600 ton updraft cooling tower of wood and fiberglass slat construction. Due to the small A/C loads, only one chiller ran during the test. Prior to the test, scale, corrosion and biofilm were controlled using an in line automated chemical feed system. Sludge build-up and TDS (total dissolved solids) were controlled by periodic blowdowns. The cooling tower slats, deck and sump were physically cleaned annually, and the condenser tubes were brushed annually. Prior to the test commencement the condenser was opened, the tubes were inspected and pictures were taken. Visible scale was observed in the inspection. As part of the test, corrosion coupons were placed in the condensing water system to monitor corrosion. Historical data on electrical usage, water intake, sewer discharge, chemical costs and labor was used in comparison with the observed data of the test. At the commencement of the test the cooling tower, condenser, piping and equipment were operating normally and within the accepted range of a "clean" system.

Observed Results:

Within a few days after the system was installed and turned on, scale on the cooling tower slats began sloughing off in large clumps. At the conclusion of the test period all scale residue had been removed from the slats, deck and other exposed surfaces. When the condenser was opened and inspected, the pre-test scale was gone and no new scale had formed. The coupons indicated no metal corrosion in the system from the use of the test equipment, or the non-use of inhibitors.

The pre-test visible green and brown live biofilm was eliminated, and the black residual line in the sump and on the tower surface was dead algae easily removed by hand wiping or brushing.

Due to the sloughing of the tower scale, the in line cartridge filter installed as part of the test system was unable to handle the load. Several blowdowns were necessary to void the sump of the scale. The in line cartridge filter was removed, and a large in line, automatic backwashing, multimedia filter was installed, after which the test system operated as designed backwashing only every third or fourth day.

The electrical draw on the one operating chiller on the condensing water loop was decreased by 40 amps while maintaining design temperature on the leaving chill water at full load conditions.

Effective Savings:

The test demonstrated immediate and significant savings for this particular test site. Within one week the electrical draw was reduced by 40 amps on the one operating chiller with a resulting savings of an estimate of $579.62 per month. If the building A/C load had required both chillers to operate, then the electrical savings would have been 40 amps on each, for twice the savings as one. The elimination of chemicals saves an estimate of $308.45 per month, plus the time and expense of inventorying, monitoring and disposal. The elimination of scale and biofilm build-up on the tower surfaces and in the condenser will result in annual labor and equipment savings of an estimated $307.20. The totally non-chemical treatment for scale and biofilm, when coupled with the test system's automatic backwashing filter, maintains TDS without blowdown. The water savings is an estimate of $78.11 per month. Because of the absence of any environmentally damaging chemicals, the backwash may be discharged without a sewer charge, with a resulting savings of an estimate of $109.77 per month. Depending on the actual number of months of operation of the HVAC system, the estimated annual savings from this invention's use at the test site is shown on Table 4.

Table 4: Estimated Annual Savings Calculation

Annual savings based on a varying season length. Based on 16 hours/day, 7 days/week.

	Monthly	7 mo	8 mo	9 mo	10 mo	11 mo	12 mo
Electrical (with only one chiller in use)	$579.62	$4,057.34	$4,636.96	$5,216.58	$5,796.20	$6,375.82	$6,955.44
Chemical	308.45	3,701.40	3,701.40	3,701.40	3,701.40	3,701.40	3,701.40
Maintenance		307.20	307.20	307.20	307.20	307.20	307.20
Water	78.11	546.77	624.88	702.99	781.10	859.21	937.32
Sewage	109.77	768.39	878.16	987.93	1,097.70	1,207.47	1,317.24
Total Savings Per Year		$9,381.10	$10,148.60	$10,916.10	$11,683.60	$12,451.10	$13,218.60

Note: Annual savings would increase by $1.29 for each hour that the second chiller was required to operate.

The elimination of scale, biofilm and corrosive chemicals significantly increases the life of the tower slats, condenser tubes, pumps, piping and valves. The exact amount of benefit from such equipment savings has not been calculated, but is expected to be significant.

Reductions in workman compensation, general liability and environmental liability from the removal of hazardous chemicals from the workplace, the tower plume mist, blowdown discharge and sludge should be likewise significant.

The actual pre and post-installation procedures will depend on the quantities of scale build-up on the tower surfaces and sludge present in the sump. Most preferably, the side system should be incorporated into a thoroughly cleaned condensing loop, wherein the scale is completely removed. Ionization of the system water helps dissolve old deposits and corrosion, but all systems should be thoroughly cleaned before installation of the treatment system to remove old scale and corrosion crusts that may be coated by chemical corrosion inhibitors, but never removed. The condensing loop and cooling tower should be throughly cleaned and inspected before installation of the treatment system, because it will cause rapid descaling that may be too much for blowdowns.

While this invention may be embodied in many different forms, there are shown in the drawings and described in detail herein specific preferred embodiments of the invention. The present disclosure is an exemplification of the

principles of the invention and is not intended to limit the invention to the particular embodiments illustrated.

This completes the description of the preferred and alternate embodiments of the invention. Those skilled in the art may recognize other equivalents to the specific embodiment described herein which equivalents are intended to be encompassed by the claims attached hereto.

WHAT IS CLAIMED IS:

1. A cooling water system having a condensing water loop, comprising:

a condenser system:

a cooling tower having water sides and a basin; and

a water treatment apparatus comprising:

a skid mounted pump having:

an inlet port and an outlet port, said inlet port being connected to an incoming water line for supply water to be treated, drawn from the condensing water loop of the cooling water system;

a first electrode ionization chamber comprising:

an inlet port and an outlet port, said pump outlet communicating with said first electrode chamber inlet; and

two ion-producing electrodes spaced apart, wherein at least one of said ion-producing electrodes comprises plasma fused iridium coated titanium;

a second electrode chamber comprising:

two ion-producing electrodes spaced apart, wherein at least one of which comprises a solid copper bar; and

an inlet port and an outlet port; and

an electronic means capable of periodically reversing the direction of the current to the electrodes and changing the polarity of the electrodes during the water treatment process so that the original anode becomes a cathode and the original cathode becomes an anode, wherein contaminants that accumulate on the electrodes are effectively flushed off, thus cleaning the electrodes,

wherein the electrode chambers communicate with the condensing water loop such that water in the loop is circulated through the electrode chambers.

2. A system according to Claim 1, wherein the water treatment apparatus further comprises an automatic backwashing multimedia sediment filter, the filter having an

inlet port and an outlet port, said pump outlet port being connected to said filter inlet port and said filter outlet port being connected to said first electrode ionization chamber inlet port.

3. A system according to Claim 2, wherein said first chamber outlet is connected to said second electrode chamber inlet port, wherein the outlet port of said second electrode chamber is connected to the condensing water loop to enable water discharged from the apparatus to be disbursed uniformly and completely over the water side surfaces of the cooling tower.

4. A system according to Claim 1, further comprising a water pickup pipe located in the cooling tower basin and connected to the inlet port of the skid mounted pump.

5. A system according to Claim 2, with the cooling tower further comprising a spray dispersal system connected to at least one of the electrode chambers so that water which exits the water treatment apparatus can be dispersed uniformly and completely over the water side surfaces of the cooling tower.

6. A system according to claim 5, wherein the spray dispersal system is connected to the first electrode chamber.

7. A system according to claim 6, further comprising a make-up water source, the make-up source being connected to the second electrode chamber inlet.

8. A cooling water system having a condensing water loop, comprising:
a condenser system;
a cooling tower having water sides and a basin; and
a water treatment apparatus comprising:
a first ionization chamber comprising:
two ion-producing electrodes spaced apart, at least one electrode being comprised of solid copper;

an inlet port and an outlet port, said inlet port being capable of being connected to an incoming water line for supplying make-up water to be treated by said chamber.

9. A system according to Claim 8, said water treatment apparatus further comprising:

a pump having an inlet port and an outlet port, said inlet port being connected to an incoming water line for supplying water to be treated by said apparatus from a condensing water loop of a cooling water system having a condenser and a cooling tower having a basin and water side surfaces;

an automatic backwashing multimedia filter having an inlet and an outlet port, wherein the pump outlet port is connected to the inlet port of the automatic backwashing multimedia filter;

a second ionization chamber comprising:

two ion-producing electrodes spaced apart, at least one electrode being comprised of a plasma fused iridium coated titanium;

an inlet port and an outlet port, the outlet port of said filter being connected to the inlet port of the second ionization chamber and the outlet port of said ionization chamber being connected to the condensing water loop for dispersal of the treated water completely and uniformly over the water side surfaces of the cooling tower.

10. A system according to Claim 9, further comprising a water pickup pipe extending from the cooling tower to the pump.

11. A system according to Claim 9, with the cooling tower further comprising a cooling tower deck water dispersal system to disperse the treated water evenly within the cooling tower.

12. A system according to Claim 8, the water treatment apparatus further including a skid mounted pump and an automatic backwashing filter and an ozonator, wherein the water from the condensing water loop is treated by passing it through the filter, the ozonator and the ionization chamber.

13. A water treatment system according to Claim 12, further including a cooling tower deck water dispersal system constructed and arranged to reintroduce the treated water into the water loop by dispersing it down the sides of the cooling tower.

14. A method of treating and cooling water in a cooling water system having a condensing water loop, comprising:

pumping water through a condensing water loop to cool and reuse the water which is heated by a condenser;

cooling the water by dispersing the heated water into a cooling tower having a basin;

drawing a portion of the water from the loop into a water treatment apparatus, the water treatment apparatus comprising:

an inlet port and an outlet port, said inlet port being connected to an incoming water line for supply water to be treated, drawn from the condensing water loop of the cooling water system;

a first electrode ionization chamber comprising an inlet port and an outlet port, said inlet port communicating with said first electrode chamber inlet, and two ion-producing electrodes spaced apart, wherein at least one of said ion-producing electrodes comprises plasma fused iridium coated titanium; and

a second electrode chamber comprising two ion--producing electrodes spaced apart, wherein at least one of which comprises a solid copper bar and an inlet port and an outlet port;

oxidizing the water by passing the portion of water through the first electrode ionization chamber, wherein one electrode acts as an original anode and the second electrode acts as an original cathode, the electrodes also being positioned in the same chamber so that the water is passed over each of the electrodes, either in sequence or substantially simultaneously;

ionizing the water by passing the water through the second electrode ionization chamber wherein one electrode acts as an original anode and the second electrode acts as an original cathode, the electrodes also being positioned in the same chamber so that the water is passed over each of the electrodes, either in sequence or substantially simultaneously;

periodically reversing the direction of the current to the electrodes and changing the polarity of the electrodes during the water treatment process so that the original anode becomes a cathode and the original cathode becomes an anode, wherein contaminants that accumulate on the electrodes are effectively flushed off, thus cleaning the electrodes; and

returning the water to the cooling loop via the cooling tower.

15. The method of claim 14, further comprising the step of filtering the portion of water through a multimedia filter constructed and arranged within the water treatment apparatus prior to oxidizing the water.

16. The method of claim 15, wherein the treated water is returned to the cooling tower via a spray dispersal system connected to at least one of the electrode chambers, constructed and arranged such that the water which exits the water treatment apparatus can be dispersed uniformly and completely over the water side surfaces of the cooling tower.

17. The method of claim 15, further comprising the step of introducing make-up water into the second ionization chamber for ionization and thereafter reintroducing the water into the cooling tower.

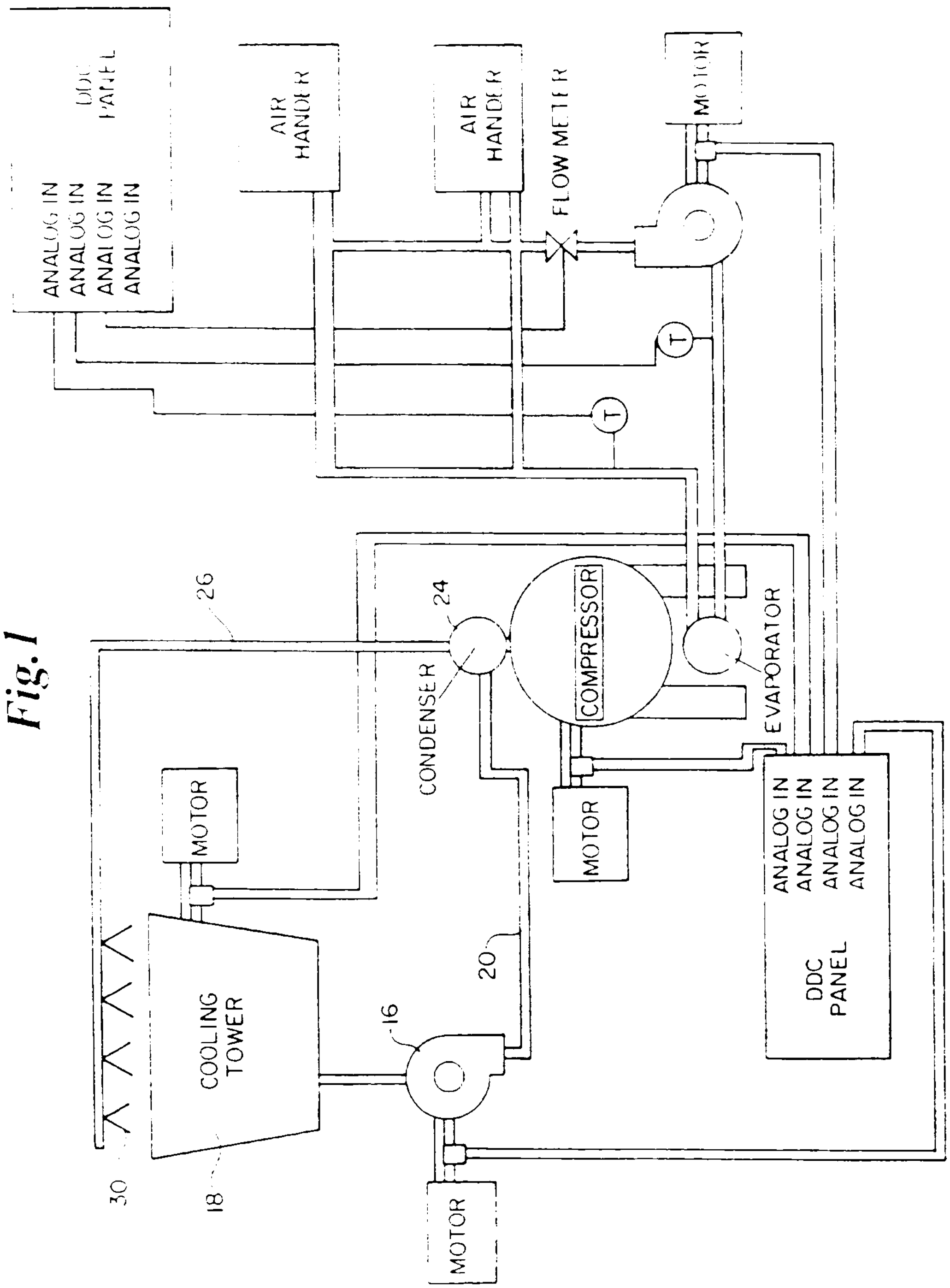
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Fig. 1

Fig.2

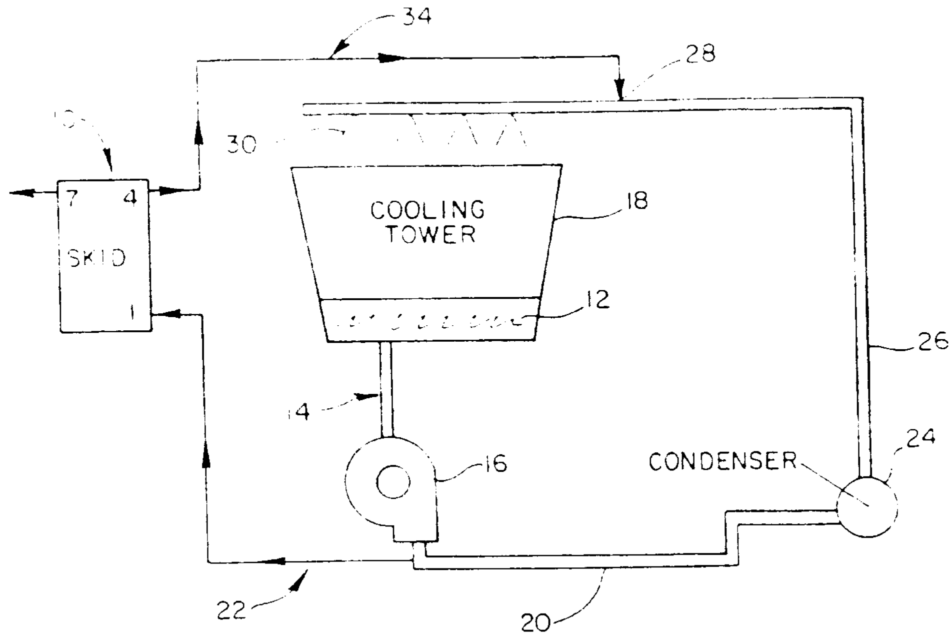
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Fig.3

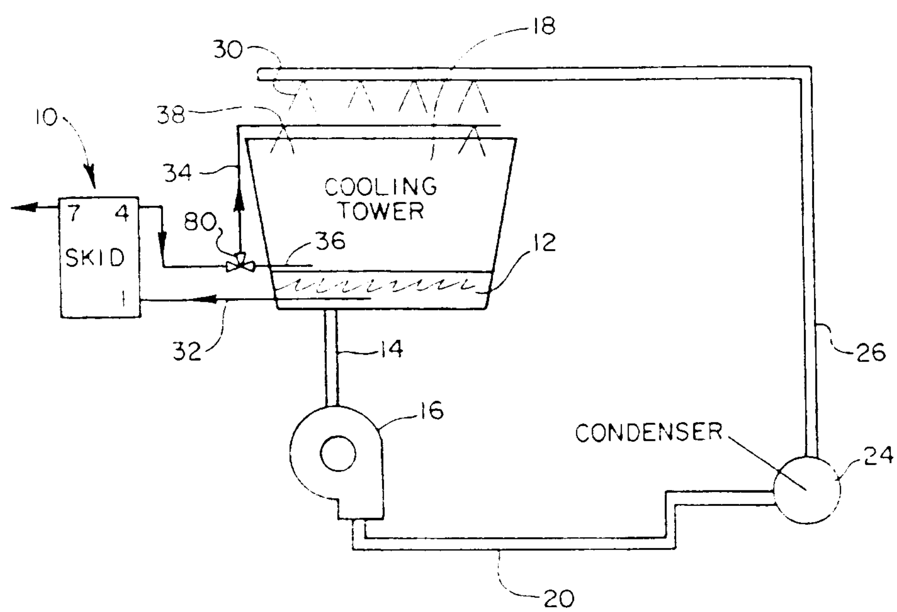
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Fig.4

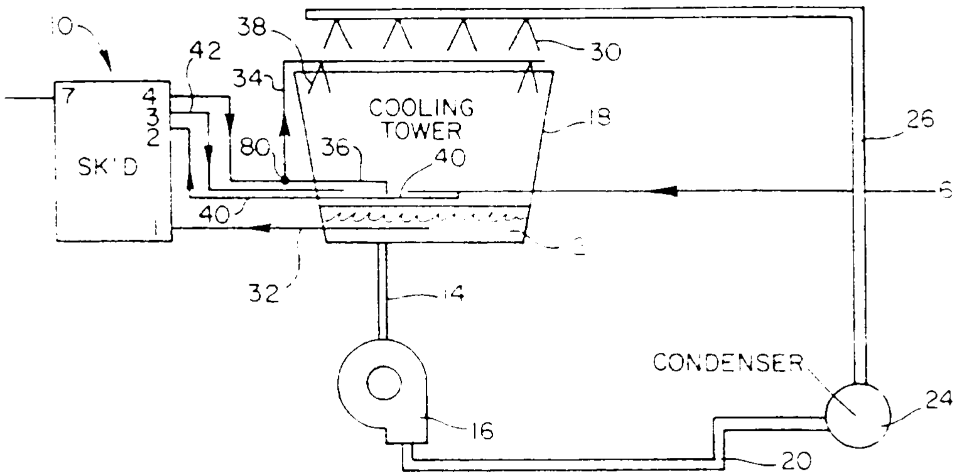
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Fig. 5a

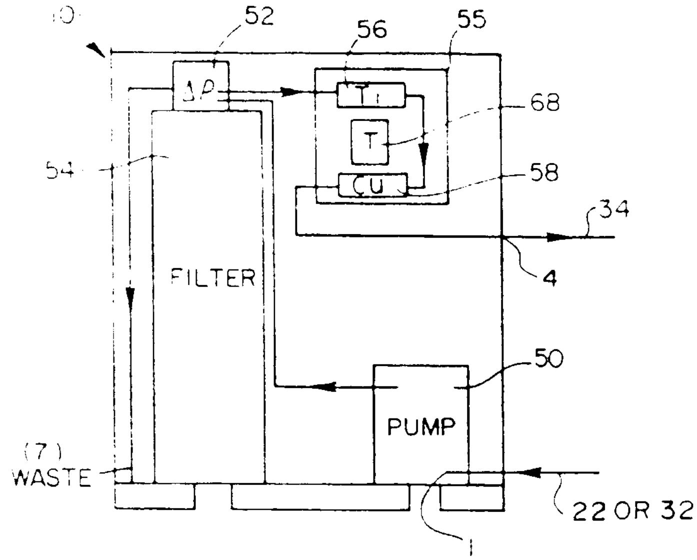


Fig 5b

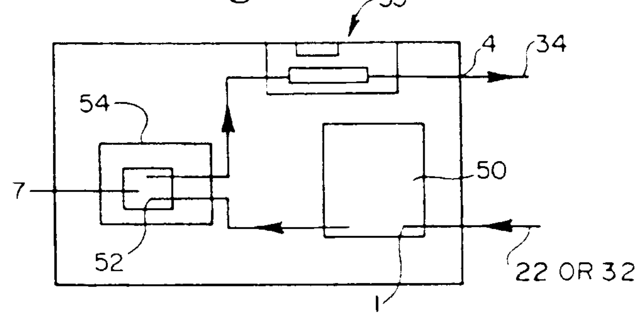


Fig. 5c

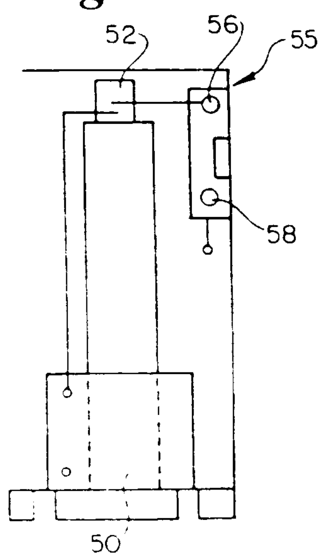


Fig. 6a

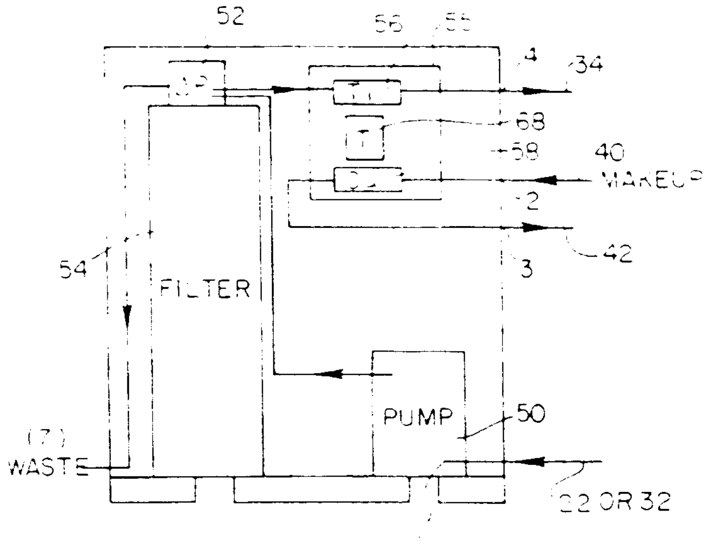


Fig. 6b

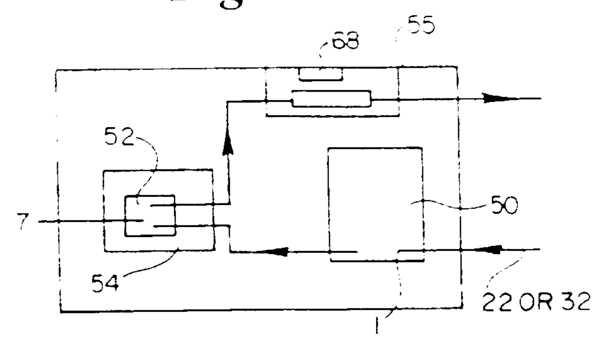


Fig. 6c

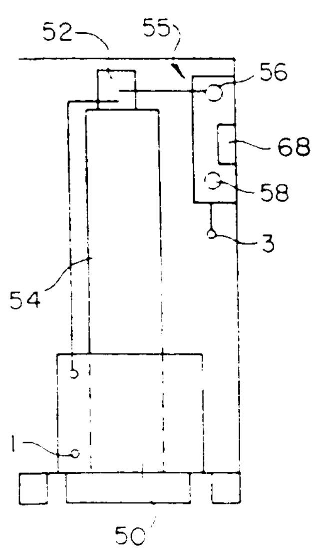


Fig. 7a

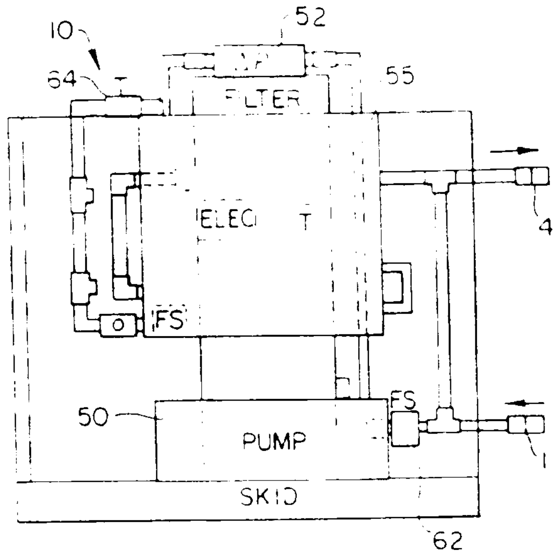


Fig. 7b

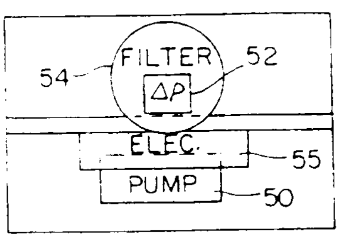


Fig. 7c

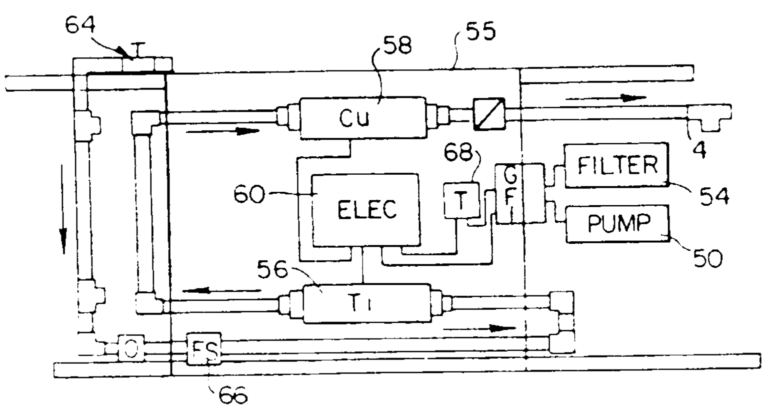
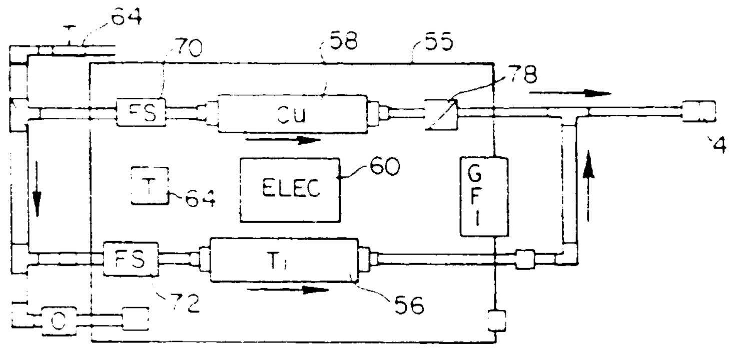


Fig.8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Ti
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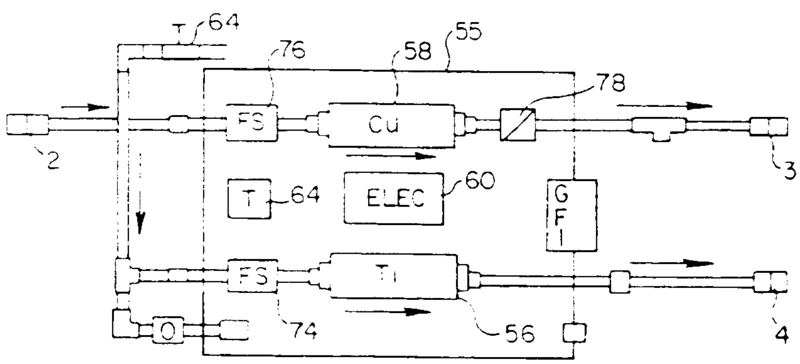
Fig.9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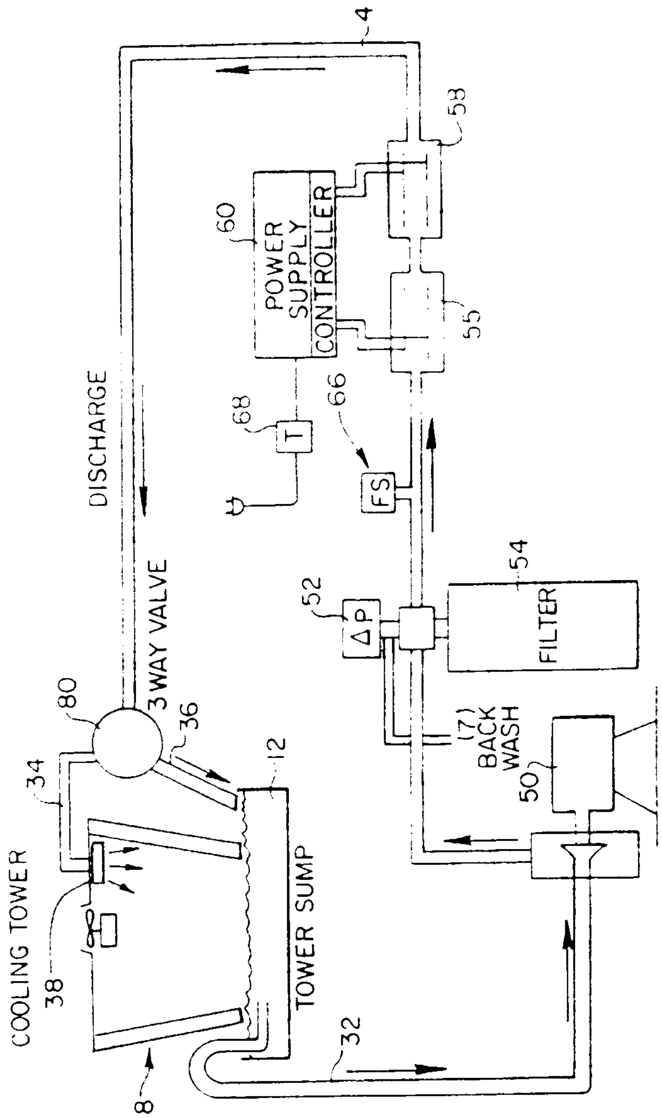
78
FS
Cu
2
3
T
64
ELEC
60
G
F
I
FS
Ti
74
56
4
O


COOLING TOWER
TOWER SUMP
3 WAY VALVE
DISCHARGE
POWER SUPPLY
CONTROLLER
FILTER
(7) BACK WASH
ΔP
FS
T
4
12
18
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68
80

Fig. 10

Fig. 11

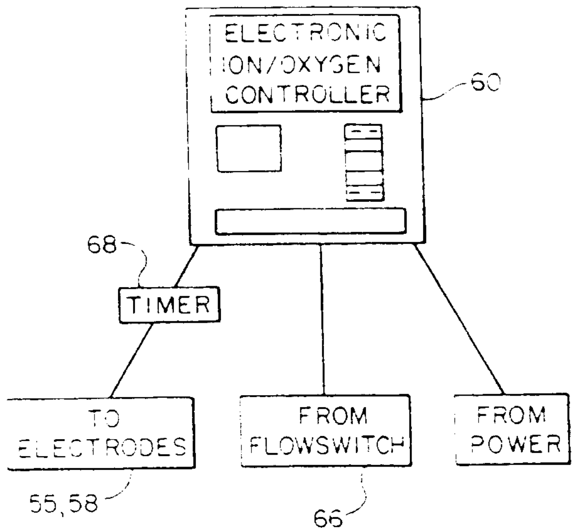


Fig. 12a

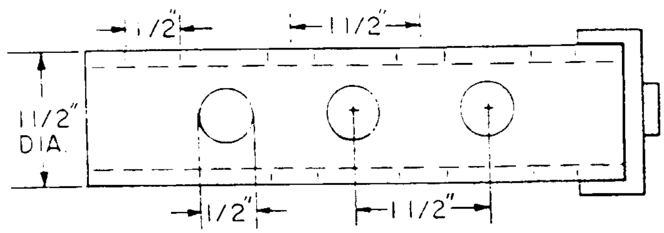


Fig. 12b

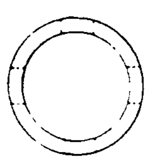
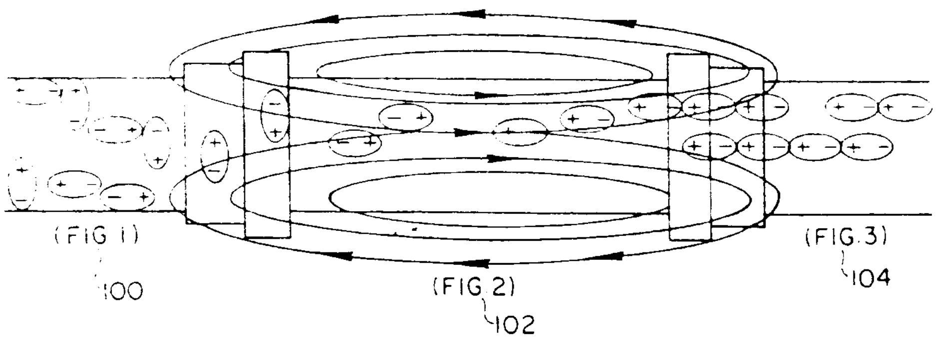


Fig. 13



INTERNATIONAL SEARCH REPORT

International application No
PCT/US97/00885

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) C02F 1/467
US CL 210/696

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. Please See Extra Sheet

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
Y	US, 4,861,489 (SWIFT ET AL.) 29 AUGUST 1989, SEE ENTIRE DOCUMENT	1-17
Y, E	US, 5,603,843 (SNEE) 18 FEBRUARY 1997, SEE ENTIRE DOCUMENT	1-17
Y	US, A, 5,173,092 (RUDDER) 22 DECEMBER 1992, SEE ENTIRE DOCUMENT	1-7, 12, 13
Y	US, A, 4,172,786 (HUMPHREY ET AL.) 30 OCTOBER 1979, SEE ENTIRE DOCUMENT	12
A	US, A, 5,007,994 (SNEE) 16 APRIL 1991, SEE ENTIRE DOCUMENT	1-17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 MAY 1997	22 MAY 1997

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00885

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

210/696, 748, 752, 758, 760, 764, 765, 793, 108, 143, 167, 181, 192, 195.1, 199, 205, 275, 277, 290; 204/240, 276, 292, 293; 205/743, 747, 751, 752, 759